NEST SITE SELECTION AND BROOD HOME RANGES OF GREATER SAGE-GROUSE (*CENTROCERCUS UROPHASIANUS*) IN THE CENTENNIAL VALLEY, MONTANA

by

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ABSTRACT

The purpose of this study was to estimate the fine-scale nest site selection of greater sage-grouse (*Centrocercus urophasianus*) and to investigate the differences in brood home range size in response to cattle grazing in the Centennial Valley, Montana. A total of 111 sage-grouse hens were captured across two breeding seasons (2014-2015). Hens were captured on leks using spotlighting/dip netting techniques. A total of 90 nests were found across both breeding seasons using radio-collared sage-grouse (VHF). Vegetation surveys were conducted at nests and random sites that measured the nest shrub and the cover within 3 m of the nest. All habitat variables that were included in the top model (GLMs) were nest shrub morphological characteristics and the cover provided by the nest shrub. It appears that sage-grouse are selecting nest sites based on the concealment provided by the nest shrub. Forty-five percent of nests were under mountain big sagebrush plants (*Artemisia tridentata ssp. vaseyana*), 21% nests were under three-tip sagebrush (*A. tripartita*), and 20% of nests were under basin big sagebrush plants (*A. tridentata ssp. tridentata*). Nests under mountain big sagebrush and three-tip sagebrush shrubs provided twice the amount of lateral cover that basin big sagebrush provided. Of the 90 nests found, 18 produced successful broods. Grazing utilization levels, grass heights, and dominant sagebrush type were recorded at brood locations and extrapolated to estimate those values across the brood's home range. Two sample t-tests were used to test if there was a difference between the habitat variables in grazed and ungrazed pastures as well as by habitat type. Grazing utilization levels were on average 4% in brood home ranges across both years of the study. There was no year effect in brood home range size and brood home range size did not differ by grazed and ungrazed pastures or across the two habitat types the broods used. Brood home range size is most likely delineated by other factor(s) besides cattle grazing. Managers should focus on conserving continuous stands of mountain big sagebrush and three-tip sagebrush habitats because they provide higher concealment for nesting and were highly used for brood-rearing.

CHAPTER ONE

INTRODUCTION

Greater sage-grouse (*Centrocercus urophasianus*, hereafter referred to as sage-grouse) is a sagebrush (*Artemisia spp.*) obligate species that has declined range-wide since the 1950s (Connelly and Braun 1997, Connelly et al. 2004, Gregg and Crawford 2009). The U.S. Fish and Wildlife Service declared that sage-grouse are not warranted for listing under the Endangered Species Act on September 22, 2015. This decision is up for review in five years (U.S. FWS 2015). The listing of sage-grouse would cause a major revision in the current multiple-use management that dominates roughly 70% of the sagebrush habitats (Box 1990, Poling 1991, Connelly et al. 2004). Historically, sagebrush covered roughly 63 million hectares (ha) in western North America, but now only a small fraction exists undisturbed or unaltered (West 1996, Miller and Eddleman 2001, Knick et al. 2003). Sage-grouse rely on the structural attributes of sagebrush habitats for food and cover (Beck et al. 2011) and sage-grouse populations are stable where large intact sagebrush habitats are present (Aldridge et al. 2008, Knick et al. 2013, Dahlgren et al. 2015). Federal land management agencies (e.g. Bureau of Land Management) manage 66% of the sagebrush habitats in the U.S. (Connelly et al. 2004).

Livestock grazing is the most prominent land use and disturbance found across the sagebrush habitats of the western U.S. (Connelly et al. 2004). Grazing leases on these public lands provide a substantial amount of forage for livestock producers. High grazing intensity associated with long duration and high stocking rates has been cited as a threat

to sagebrush habitats (Beck and Mitchell 2000, Hayes and Holl 2003, Crawford et al. 2004, Aldridge et al. 2008). How livestock grazing affects the density and cover of shrubs in sagebrush has been debated with evidence on both sides of the issue. Laycock (1979) found that sagebrush increased after herbaceous production was hindered by intense spring grazing by cattle and sheep. Contrary, Peterson (1995) literature review found no evidence that livestock grazing increased sagebrush distribution. Livestock grazing can affect the overall herbaceous productivity in sagebrush habitats depending on the timing, duration, and intensity of the grazing (Holechek and Stephenson 1983, West et al. 1984, Laycock 1991, Beck and Mitchell 2000). However, Van Poolen and Lacey (1979) concluded that stocking rate was the main factor controlling herbage production and not what grazing system used (e.g. continuous, rest-rotation, deferred rest-rotation). Removal of nesting cover due to grazing has been shown to increase predation and alter nest site selection (Gregg et al. 1994). Delong et al. (1995) found using artificial nests, that nests under medium-height shrubs (40-80 cm) and with >10% grass cover were depredated less than nests under medium-height shrubs and with <10% grass cover. It is well documented that sage-grouse generally nest under shrubs that have larger canopies and more cover than other nearby shrubs with the majority of those shrubs being sagebrush plants (Connelly et al. 2000). Although, the scales at which the vegetation attributes were measured near the nest site vary across studies. The transects used to measure the vegetation varied in number (2-4 transects) ranged from 10-50m long (Connelly et al. 1988, Johnson and Boyce 1990, Drut et al. 1994a, Hagen et al. 2007, Fedy et al. 2012). Coates and Delehanty (2008) found that sage-grouse spend 96% of

their time on their nest during the 28 day long incubation period. Therefore, a large majority of the time the only habitat that is providing cover to an incubating sage-grouse hen is within a close proximity to the nest site (i.e. the vegetation within several meters that provides concealment). This suggests that in determining nest site selection of sage-grouse, researchers should focus at a fine-scale around the nest. Focusing on the attributes of the nest shrub (e.g. species, structure, morphology) and the vegetation cover within a close proximity of the nest shrub may provide additional information to aid in the conservation of this species.

Indirect effects of cattle grazing such as the removal of nesting cover has been widely studied, but the direct effects of cattle on sage-grouse are not well understood (Beck and Mitchell 2000). Direct effects such as cattle presence to sage-grouse have not been specifically studied. Cattle have been believed to cause nest abandonment, but how their presence and herbivory effect broods (i.e. hen with ≥1 chick) have not been studied (Coates et al. 2008). Whether broods select for or against cattle grazed pastures has been sparsely studied, mainly due to low sample sizes (e.g. n=1; Lupis 2005). Furthermore, testing whether brood home range size differs across pastures with and without livestock could have potential management implications (Beck and Mitchell 2000, Hayes and Holl 2003, Crawford et al. 2004, Aldridge et al. 2008). Also, estimating how brood home ranges are affected by pastures occupied by livestock and at what the utilization levels are in brood home ranges will provide insight to estimate the effects that cattle grazing have on the area used by broods. Utilization is defined as percent of current year's growth removed on a dry weight basis (Coulloudon et al. 1999). Estimating how heavy of use by

livestock that sage-grouse broods can tolerate will contribute to the conservation of this species.

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CHAPTER TWO

GENERAL METHODS

Sage-grouse hens were captured near leks using a combination of spotlighting/dip netting techniques and rocket nets during the spring breeding season (Giesen et al. 1982, Wakkinen et al. 1992). Animal care protocols were approved by IACUC #017-12MAWEST-042412 (4/15). Immediately after capture hens were aged, banded and collared. Hens were banded with a size #14 National Bands and Tag (Newport, KY). The hens were fitted with VHF transmitters (American Wildlife Enterprise, Monticello, FL) and then released. VHF transmitters weighed 13 g, which is <1% of sage-grouse overall weight. Captures took place during the spring breeding season when sage-grouse were concentrated on leks. The first season of captures commenced on April 12, 2014 and ended on April 24, 2014 (n=51 hens). The second season of captures began March 27, 2015 and ended on June 21, 2015 (n=60 hens). These additional birds were captured to replace sage-grouse that were lost due to mortalities and collar failures during the previous year and to increase our sample size. Technicians underwent training in capturing and handling techniques to minimize unnecessary stress to the captured sage-grouse.

Locations of collared hens were determined using Yagi antennas. Locations were recorded several times a week throughout the nesting season to determine nest locations and nest status (e.g. active/failed). Locations during the pre-breeding and nesting period were determined by using triangulation, circling, or by visual observations via flushing

the hen. Triangulation using compass bearings from two to three different positions and circling the bird at least 50 m away were used 2/3 of the time in order to avoid stressing the sage-grouse during the nesting season with our presence. After every two locations determined by triangulation, a location was determined by visual observation. A visual observation provided reproductive status of whether the hen is laying or incubating and the exact nest location.

The locations were recorded several times a week throughout the brood-rearing season to determine habitat selection and home ranges. Once a week, each brood was flushed in the pre-dawn hours in order to determine if the brood was still active with ≥1 chicks. Broods were monitored until the chicks were 30 days old. The chicks became largely independent and no longer relied on their mother for thermoregulation at ~30 days old. Flushing broods after 30 days resulted in a possible failure to detect chicks (Schroff, *personal observation*). Therefore, in order to have an accurate estimation of whether the brood was successful we only monitored broods until the chicks were 30 days old. Chick mortality most often occurs within 28 days post-hatch (Gregg et al. 2007, Dahlgren et al. 2010). A brood was declared successful if ≥1 chick survived to 30 days post-hatch and at that point they were no longer monitored.

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CHAPTER THREE

FINE-SCALE NEST SITE SELECTION OF GREATER SAGE-GROUSE (*CENTROCERCUS UROPHASIANUS*) IN THE CENTENNIAL VALLEY, MONTANA

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Contributions: Conceived and implemented the study design. Collected and analyzed the data. Wrote first draft of the manuscript.

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Co-Author: Dr. Craig A. Carr

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Contributions: Conceived and implemented the study design. Provided field expertise and feedback on early drafts of the manuscript.

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CHAPTER THREE

FINE-SCALE NEST SITE SELECTION OF GREATER SAGE-GROUSE (*CENTROCERCUS UROPHASIANUS*) IN THE CENTENNIAL VALLEY, MONTANA

Abstract

The purpose of this study was to estimate fine-scale nest site selection of greater sage-grouse (*Centrocercus urophasianus*) in the Centennial Valley, MT. A total of 90 nests were found during 2014-2015 using radio-collared sage-grouse. Vegetation surveys were conducted at nests (n=90) and random sites (n=89) that measured the nest shrub and the cover available within 3 m of the nest. The majority of the nests were located under sagebrush (*Artemisia spp.*) plants with 45% under mountain big sagebrush (*Artemisia tridentata ssp. vaseyana*), 21% under three-tip sagebrush (*A. tripartita*), and 20% under basin big sagebrush (*A. tridentata ssp. tridentata*). Generalized linear models (GLMs) were used to estimate nest site selection. The top model contained nest shrub morphological characteristics and the cover provided by the nest shrub. None of the habitat variables associated with herbaceous cover received support for inclusion in our models. Residual cover (i.e. grass from previous year) provided concealment for only 4% of the nest bowl. Mountain big sagebrush and three-tip sagebrush shrubs provided twice the amount of lateral cover that basin big sagebrush shrubs provided. Managers should focus on conserving mountain big sagebrush and three-tip sagebrush habitats because they were more likely to meet those shrub characteristics that were selected for nesting.

Keywords: Greater sage-grouse (*Centrocercus urophasianus*), nest site selection, sagebrush (*Artemisia spp.*), herbaceous cover, habitat type

Introduction

Greater sage-grouse (*Centrocercus urophasianus*, hereafter referred to as sage-grouse) is a sagebrush (*Artemisia spp.*) obligate species that has declined range-wide since the 1950s (Connelly and Braun 1997, Connelly et al. 2004, Gregg and Crawford 2009). Sage-grouse rely on the structural attributes of sagebrush habitats for food and cover (Beck et al 2011). It is well documented that sage-grouse generally nest under shrubs (mainly sagebrush) that have larger canopies and more cover than other nearby shrubs (Connelly et al. 2000). The scales at which the vegetation attributes were measured to characterize nest sites vary from 10-50 m around nests (Connelly et al. 1988, Johnson and Boyce 1990, Drut et al. 1994a, Hagen et al. 2007, Fedy et al. 2012). Coates and Delehanty (2008) found that sage-grouse spend 96% of their time on their nest during the incubation period (28 days long). For the majority of the time the only habitat that is providing cover to an incubating sage-grouse is in close proximity to the nest site. Therefore, the focus should be on the vegetation within several meters that provides concealment to the nest and the incubating hen. Grass cover and grass heights are greater at nest sites than at random sites (Wakkinen 1990, Gregg 1991, Sveum et al. 1998, Conover et al. 2010, Lockyer et al. 2015). Shrub canopy cover and shrub height have also been cited as important habitat variables sage-grouse select for in a nest site (Connelly et al. 2000). Sagebrush canopy cover of 15-25% is recommended for nesting habitat

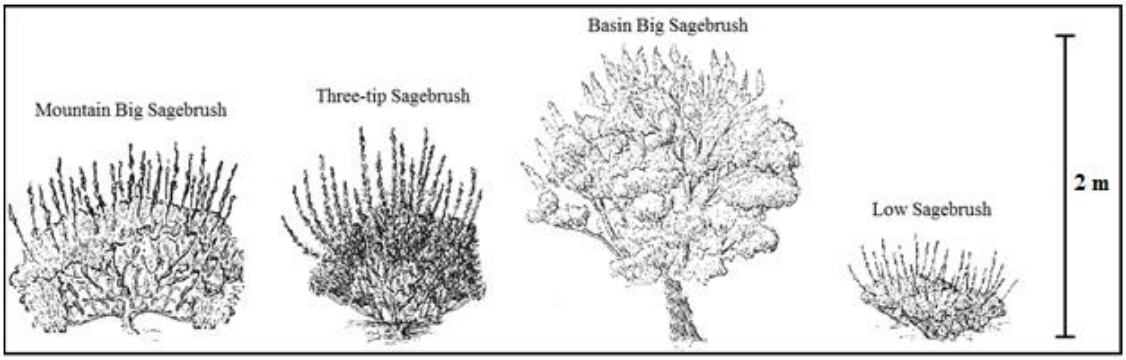
(Connelly et al. 2000), but some sites >40% shrub cover are selected for nest sites (Lockyer et al. 2015). Twenty-nine to 80 cm is the average shrub height that sage-grouse select for as a nest site (Keister and Willis 1986, Wakkinen 1990, Apa 1998, Connelly et al. 2000). Although, shrubs 20-25 cm tall have been used as nest sites, especially in less productive areas where taller shrubs are not present (Lane 2005). Connelly et al. (2000) recommends to that sagebrush canopy cover should be 15-25%, grass cover ≥15%, forb cover ≥10% and with herbaceous heights averaging ≥18 cm for nesting habitat. Due to the substantial variation in vegetation across different sagebrush types one might reason that sage-grouse habitats need to be managed at local scales (Connelly et al. 2000, Kolada et al. 2008). Different vegetation communities and local conditions may alter sage-grouse selection of nest sites due to variability of habitats.

Methods

Study Area

Our study area was located in the Centennial Valley of southwest Montana. This high elevation (>2000 m) valley contains large expanses of sagebrush habitats that include several leks that belong to a sparsely studied population of sage-grouse. The Centennial Valley is within the Montana Sage-Grouse Core Area 10. The Core Areas of Montana represent <10% of the land area, but support >50% of the sage-grouse population in the state (NRCS 2010, Foster et al. 2015). Eight leks found across the entire length of the valley (~100 km) were where captures took place. The Fish Creek Lek was the largest lek which had an average of 100 males in the previous five years (US FWS,

unpublished data). The sage-grouse captured at those eight leks dispersed to ~40,000 ha. The four main sagebrush species found in our study area are mountain big sagebrush (*Artemisia tridentata ssp. vaseyana*), three-tip sagebrush (*A. tripartita*), basin big sagebrush (*A. tridentata ssp. tridentata*), and low sagebrush (*A. arbuscula*; US FWS 2009)**.** Mountain big sagebrush is a moderately to large sized shrub located at higher elevations, where there is more precipitation and generally has higher herbaceous cover. Also, it has many lower lateral branches and was dominant in 63% of the study area (Fig. 1). Three-tip sagebrush is a moderately sized shrub located at moderate elevations, where there is moderate amount of precipitation and generally has moderate/high herbaceous cover. Also, it has many lower lateral branches and was dominant in 25% of the study area. Basin big sagebrush is a large tree-like shrub with higher lateral branches located at lower elevations, where there is less precipitation, less herbaceous cover, and was dominant in 8% of the study area. Low sagebrush is a small shrub with short lateral branches located at lower elevations, where there is less precipitation and generally less herbaceous cover, and was dominant in 4% of the study area (Wambolt and Frisina 2002).



Shrub Type	Elevation	Precipitation	Herbaceous Cover	Nesting Cover
Mountain Big Sagebrush	High	High	High	High
Three-tip Sagebrush	Moderate	Moderate/High	Moderate	Moderate/High
Basin Big Sagebrush	Low	Low	Low	Low
Low Sagebrush	Low	Low	Low	Low

Original Illustrations by Linda A. Vorobik (Shultz 2012); modified by Sean R. Schroff

Figure 1**.** Descriptions of the structure and habitat characteristics of the four main sagebrush species/subspecies relative to each other that are found in the Centennial Valley, MT, 2014-2015.

Field Methods

Hens were captured near leks using a combination of spotlighting/dip netting techniques and rocket nets during the spring breeding season (Giesen et al. 1982, Wakkinen et al. 1992). Immediately, after capture hens were aged, banded and collared. The hens were fitted with VHF transmitters (American Wildlife Enterprise, Monticello, FL) and then released. VHF transmitters weigh 13g (<1% of sage-grouse overall weight). Locations of collared hens were determined using Yagi antennas and were recorded

several times a week throughout the nesting season to determine nest locations and nest status.

Vegetation surveys were conducted at each nest site as soon as possible after the hen had moved >250 m from site, so field surveys would not negatively affect sage-grouse broods or renesting attempts. At each nest site the nest shrub species and morphological attributes were recorded. The nest shrub morphological measurements that were recorded included nest shrub height, two axis widths (~90° from each other beginning with the widest part of shrub), and height of shrub branch over nest, and length of shrub branch over nest. An aerial cover estimate was made by estimating the amount of cover (%) directly over the nest bowl that provided concealment for the nest from an aerial predator such as a raven (*Corvus corax*). This estimate was separated by vegetative species and plant status (e.g. alive or dead). Alive plant status was designated to current year's growth regardless of senescence and dead plant status was designated as any previous growing season growth. Another estimate was made along a 1 m circle around nest shrub to estimate the amount of lateral cover (°) that was providing concealment for the nest from a ground predator such as a coyote (*Canis latrans*). The lateral cover estimates were recorded at the head height of an incubating sage-grouse (~13 cm) and were recorded in degrees in the field for ease of estimation, but were later converted into a percentage for data analysis. Also, a line-point intercept (LPI) was used to measure vegetation species cover, heights, and status at every 0.5 m along three 3 m transects (Herrick et al. 2005). Transects started at the nest shrub and radiated at ~120° from each other (Fig. 2). Similar nest shrub measurements were conducted at paired random sites

that were within 100-300 m away from the nest site. Paired random sites were used to compare between sites with similar habitat conditions (e.g. aspect, slope, precipitation). Ensuring, the differences between sites are more likely to be from the selection of the hen and not due to different habitat conditions. These random sites were used in comparison to nest sites to estimate nest site selection. The paired random nest shrub was the same species as the nest shrub and was ≥35 cm tall (Connelly et al. 2000). We made an artificial nest bowl under the random nest shrub for a reference in order for the measurements to be comparable to the actual nests. The artificial nest bowl was located in the most likely spot a hen would nest if it had chosen that shrub (i.e. the most concealed site). Nest success and other fitness metrics were recorded and are currently being analyzed by Kyle Cutting (PhD candidate) and will not be included in this thesis.

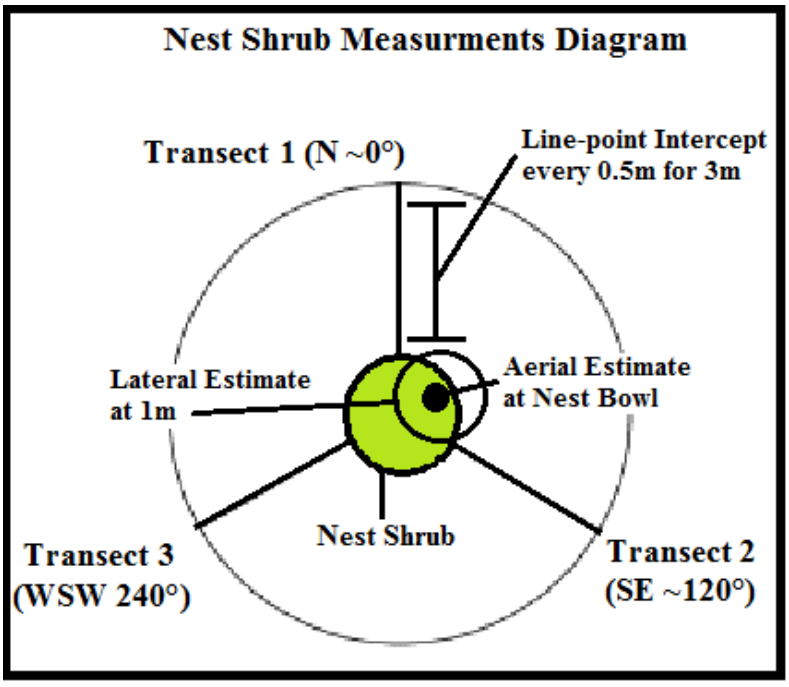


Figure 2. Habitat measurements taken at greater sage-grouse nest sites in the Centennial Valley, MT, 2014-2015.

Statistical Analyses

Nests and random points were listed as binary responses (nests=1, randoms=0) for all analyses testing nest site selection. Multiple correlations were tested to determine if any habitat variables were correlated with each other. Only the two axis measurements were highly correlated ($r>0.7$). Therefore, an average was used for that variable in the analyses. Generalized additive models (GAMs) were used to investigate potential nonlinear relationships of the habitat variables (McNew et al. 2015). GAMs help identify if a habitat variable needed to be transformed to account for a nonlinearity relationship. Resource selection functions (RSFs) for nest sites and random locations were evaluated following a Design II approach where nest sites and random locations are considered independent from each other (Manly et al. 2002). Generalized linear models (GLMs) were used to evaluate the logistic models for the habitat variables separately and combined (McNew et al. 2015). I used Akaike's information criterion corrected by small sample sizes (AIC_c) to rank models (Burnham and Anderson 2002). Each habitat variable was transformed by the natural log to test for pseudothreshold relationships (Dugger et al. 2005, McNew et al. 2015), I function which inhibits the changing of vectors to factors, and z transformation which scales the data for comparability. A candidate set of models was used to test those transformations against the null (i.e. habitat variable not transformed) to estimate which transformation or lack thereof best represented that habitat variable. I created another candidate set of models that included all top models for the fifteen habitat variables (Burnham and Anderson 2002). A final set of candidate models was created from the top models from that analysis. This final set of candidate

models combined all highly supported habitat variables into one model then the proceeding models had the least supported habitat variable excluded from the previous model until the last model included only one habitat variable (i.e. most supported habitat variable). All models that had Akaike weights (w_i) >0 were included in the results. Any models with ≤2 AIC_c values from the top model were considered competitive. All analyses were conducted in the statistical software program R Studio (version 3.1 R Development Core Team 2015, Vienna, Austria).

Results

A total of 90 nests (renests= 10) were found during 2014-2015. Each nest had a paired random location with the exception of one (n=89). All nests were located under a shrub with one exception which was located in a patch of basin wildrye (*Leymus cinereus*). The nest shrub morphological measurements were nonexistent for this nest and were excluded from the analyses. Eighty-nine percent nests were under a sagebrush plant. Mountain big sagebrush was the most common shrub used as a nest site (45%), followed by three-tip sagebrush (21%), and basin big sagebrush (20%; Table 1). Low sagebrush was not used as a nesting site by any of the collared sage-grouse.

Table 1. Shrub species/subspecies used for nest sites by greater sage-grouse in the Centennial Valley, MT, 2014-2015.

Nest Shrub Species	**2014**		**2015**		**All Years**	
	N	**%**	**N**	**%**	**N**	**%**
Mountain Big Sagebrush	14	34	25	51	39	45
Three-tip Sagebrush	8	17	11	23	19	21
Basin Big Sagebrush	11	27	7	14	18	20
Rubber Rabbitbrush	2	6	2	4	4	4
Green Rabbitbrush	2	6	2	4	4	4
Silver Sagebrush	2	6	1	2	3	3
Gray Horsebrush	1	2	1	2	2	2
Basin Wildrye*	1	2	0	0	1	1
Total	**41**	**100**	**49**	**100**	**90**	**100**

*Grass species

A single model with that included the length of the branch over nest (Lgth.LB), average axis width (AvgAxis), lateral cover of the nest shrub (LCShrub), aerial cover of the nest shrub (ACShrub), and height of lower branch over nest (Ht.LB) received the most support ($\Delta AIC_c = 0.00$; Table 2). Also, a model with Lgth.LB, AvgAxis, LCShrub, ACShrub, Ht.LB, and average grass height (AVGGrassHt) was competitive ($\Delta AIC_c<2$ from the top model). All other habitat variables including those based on herbaceous cover received little support in estimating nest site selection.

Table 2. Model selection results for greater sage-grouse nest site selection in the Centennial Valley, MT, 2014-2015.[1]

Model factors	**K**[2]	**AIC$_c$**[3]	**ΔAIC$_c$**	**W$_i$**
Lgth.LB[4] + Avg.Axis[5] + LCShrub[6] + ACShrub[7] + Ht.LB[8]	6	176.61	0.00	0.52
Lgth.LB[4] + Avg.Axis[5] + LCShrub[6] + ACShrub[7] + Ht.LB[8] + AvgGrassHt[9]	7	177.80	1.19	0.29
Lgth.LB[4] + Avg.Axis[5] + LCShrub[6] + ACShrub[7] + Ht.LB[8] + AvgGrassHt[9] + NSHt[10]	8	179.74	3.13	0.11
Lgth.LB[4] + Avg.Axis[5] + LCShrub[6] + ACShrub[7]	5	180.97	4.37	0.06
Lgth.LB[4] + Avg.Axis[5] + LCShrub[6]	4	183.16	6.55	0.02
Constant (null)	1	250.16	73.55	0.00

[1]Only models with Akaike weights (W$_i$) $\geq$0.01 are presented except the null model

[2]K= number of parameters

[3]AIC$_c$ indicates criterion adjusted for small sample sizes

[4]Length of lower branch over nest

[5]Average width of nest shrub

[6]Lateral cover provided by nest shrub

[7]Aerial cover provided by nest shrub

[8]Height of lower branch over nest

[9]Average grass height around nest shrub

[10]Nest shrub height

On average, residual cover (Lateral Cover by Residual Grass) provided concealment for only 4% of the nest bowl and live grass cover (Lateral Cover by Live Grass) had little support in the set of candidate models (Table 3). Also, 52% of the nests had no residual cover present, which includes pastures that have been rested >6 years.

Table 3. Mean ± standard error (SE) of habitat measurements at greater sage-grouse nest sites and random locations in the Centennial Valley, MT, 2014-2015.

Variables	**Nests (n=90)**	**Random Points (n=89)**
Nest Shrub Height (cm)	75.3 ± 5.7	66.7 ± 2.7
Height of Lower Branch (cm)	21.4 ± 0.6	19.9 ± 1.0
Length of Lower Branch (cm)	56.8 ± 2.0	37.8 ± 1.9
Average Axis Width (cm)	105.6 ± 3.3	77.7 ± 3.4
Aerial Cover by Shrub (%)	75.5 ± 2.6	57.7 ± 2.9
Aerial Cover by Forb (%)†	0.15 ± 0.1	0.1 ± 0.1
Aerial Cover by Grass (%)†	1.4 ± 0.9	0.7 ± 0.2
Lateral Cover by Shrub (%)	48.9 ± 2.7	30.1 ± 2.2
Lateral Cover by Forb (%)‡	4.0 ± 0.7	4.5 ± 0.8
Lateral Cover by Live Grass (%)	15.6 ± 1.8	14.1 ± 2.8
Lateral Cover by Residual Grass (%)‡	3.8 ± 0.8	2.7 ± 0.6
Shrub Cover at 3m (%)	38.0 ± 1.8	36.1 ± 1.7
Forb Cover at 3m (%)	8.6 ± 1.1	9.8 ± 1.1
Grass Cover at 3m (%)	40.7 ± 2.2	43.4 ± 2.2

Bare Ground at 3m (%)	12.2 ± 1.7	11.1 ± 1.5
Average Shrub Height (cm)	46.5 ± 1.6	47.0 ± 1.8
Average Forb Height (cm)	12.3 ± 0.8	12.4 ± 0.7
Average Grass Height (cm)	21.6 ± 1.1	19.8 ± 0.8

†On average provided aerial concealment for <2% of the nest bowl

‡On average provided lateral concealment for <5% of the nest bowl

The nest shrub provided the majority of the cover for the nest. The amount of LCShrub available was dependent on the shrub species/subspecies that the nest was located under (Fig. 3). Mountain big sagebrush and three-tip sagebrush nest shrubs provided double the amount of lateral cover that basin big sagebrush provided. Herbaceous cover provided the remaining cover to the nest.

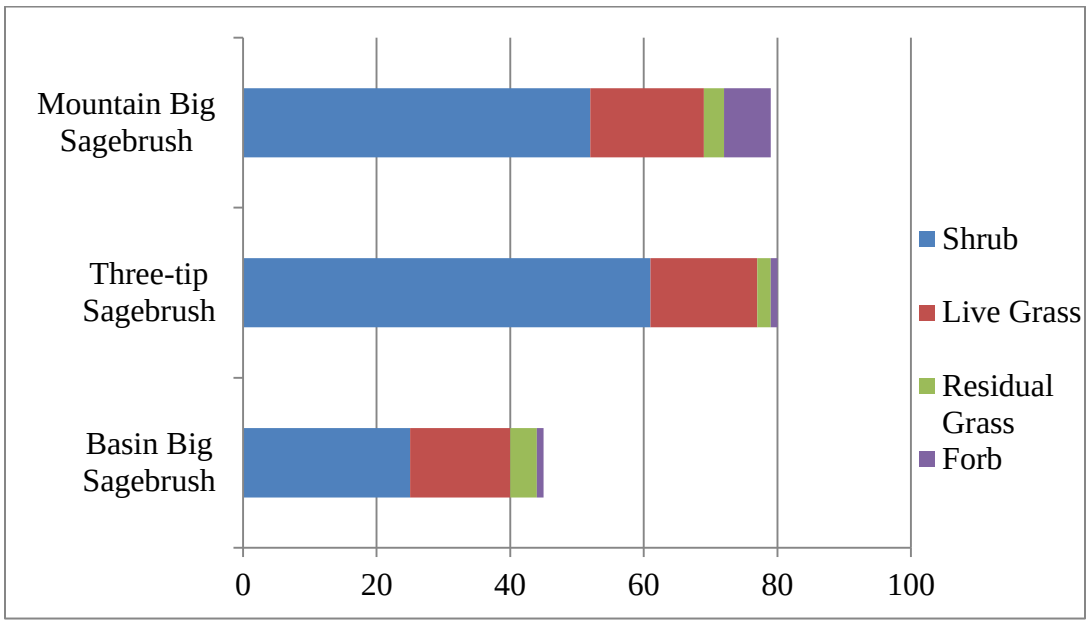


Figure 3. Lateral cover of greater sage-grouse nest sites in the Centennial Valley, MT, 2014-2015.

The probability of a shrub being selected for a nest site is maximized when the length of the lower branch (Lgth.LB) is >75cm long, average width of the shrub (AvgAxis) is >130cm wide, lateral cover provided by the shrub (LCShrub) is >80%, and the aerial cover provided the shrub (ACShrub) is >70% (Fig. 4). Sage-grouse are selecting nest sites under shrubs that have longer lower lateral branches, are wider, more shrub lateral cover, and more shrub aerial cover. Therefore, large shrubs with more cover close to the ground and more overhead cover offer the concealment that is more likely to be selected as a nest site.

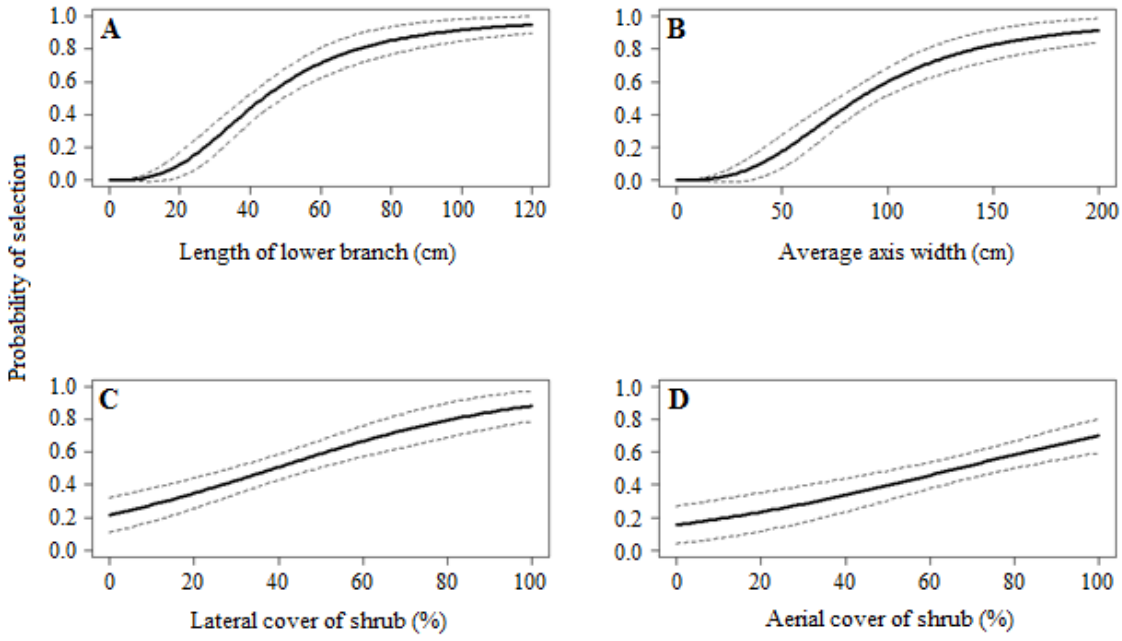


Figure 4. The probability of selection for **A,** length of lower branch, **B,** average axis width, **C,** lateral cover of shrub, and **D,** aerial cover of shrub for a nest site of greater sage-grouse in the Centennial Valley, MT, 2014-2015. Solid lines represent the means and dotted lines represent the 95% confidence intervals.

Discussion

Sagebrush plants represented 89% of the shrubs used as nest sites in our study area and 66% of all the nests were located under a mountain big sagebrush or three-tip sagebrush plant. On average, mountain big sagebrush and three-tip sagebrush provided >50% lateral cover to the nest, whereas basin big sagebrush provided 25%. Basin big sagebrush has a taller, more upright growth form with less lower level cover (Beetle and Young 1965, Winward and Tisdale 1977, McArthur et al. 1979). These properties suggests that sage-grouse are more likely to select a nest site under mountain big sagebrush and three-tip sagebrush than basin big sagebrush due to the additional lateral cover provided by those species/subspecies. Mountain big sagebrush has been shown to be selected more often as a nest site than other subspecies of big sagebrush (Kirol et al. 2012). All the other non-sagebrush shrubs that were used as nest sites were located in basin big sagebrush habitats. However, comparison between non-sagebrush plants and other shrubs was not possible due to low samples sizes (n=10). In terms of providing nesting cover to sage-grouse, basin big sagebrush may not be an adequate nest shrub. However, in other times of the year basin big sagebrush may be important to sage-grouse. In severe winters, where snow levels are high enough to cover other species of sagebrush it may be the only food source that is available above the snow level (Dahlgren et al. 2015). Severe winters have been shown to negatively affect survival rates of sage-grouse (Moynahan et al. 2006, Anthony and Willis 2010). Therefore, basin big sagebrush may be an important habitat type outside the breeding season.

Nest success is often regulated by the amount of cover available that provides concealment to nesting sage-grouse (Holloran et al. 2005, Coates and Delehanty 2010, Doherty et al. 2010, Taylor et al. 2012). Therefore, sage-grouse that select for more cover at their nest site have a higher chance of survival. All habitat variables included in the top model were nest shrub morphological measurements or cover provided by the nest shrub. It appears that sage-grouse in the Centennial Valley are selecting nest sites based on the morphology of the nest shrub and the cover provided by that nest shrub. Sage-grouse in Mono County, California attempted to maximize concealment of their nest sites by shrubs as their main source of cover (Kolada et al. 2008). Residual grass cover was not selected for, even though there were sites available where greater residual grass cover was present (Kolada et al. 2008). Residual grass cover concealed on average 4% of the nest in our study area. France et al. (2008) found that when cattle removed 75% of the standing herbaceous cover under a sagebrush plant it resulted in a 5% decline in lower-level obstruction, which suggests sagebrush represents the bulk of the intervening vegetation for nest concealment and not herbaceous cover. Connelly et al. (2000) recommends leaving >18 cm of residual grass height to provide concealment for nesting sage-grouse. However, in high elevation sites, persistent snow accumulation can compress vegetation, which may result in little residual cover available in the spring when sage-grouse are nesting (Swanson et al. 1988). The Centennial Valley receives ~1 m of snow a year which results in the residual cover being flattened and unavailable during the nesting season (US FWS 2009). Therefore, if residual cover is unavailable then sage-grouse will select for other forms of concealment for their nest (Fig.5).

Figure 5. Residual cover flattened by snowfall and unavailable to provide concealment for a nesting greater sage-grouse.

In our study area, the nest shrub and new growth of grasses/forbs are the herbaceous cover that is available. Therefore, managing for more residual cover may not provide any additional concealment to nests the following spring in our study area. In conclusion, there is substantial variability in the habitat variables that support nesting sage-grouse and local variation in habitat should be accounted for when managing sage-grouse habitats (Kolada et al. 2008). Residual cover may not be an important selection factor for nesting sage-grouse in mountain big sagebrush and three-tip sagebrush habitat types, but may play a bigger role in basin big sagebrush habitats outside our study area. Mountain big sagebrush and three-tip sagebrush provided the most lateral cover and were where the majority of nest sites were located. Therefore, those habitats should be kept intact in order to conserve nesting habitat for sage-grouse in the Centennial Valley, Montana.

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CHAPTER FOUR

BROOD HOME RANGE SIZES OF GREATER SAGE-GROUSE IN RESPONSE TO CATTLE GRAZING IN THE CENTENNIAL VALLEY, MONTANA

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CHAPTER FOUR

BROOD HOME RANGE SIZES OF GREATER SAGE-GROUSE IN RESPONSE TO CATTLE GRAZING IN THE CENTENNIAL VALLEY, MONTANA

Abstract

The purpose of this study was to investigate the differences in brood home range size and grass heights in response to cattle grazing in the Centennial Valley, Montana. A total of 111 sage-grouse hens were captured across two breeding seasons (2014-2015) and were fitted with VHF collars. These collared sage-grouse initiated 90 nests which produced 18 successful broods (i.e. ≥1 chick survived to 30 days post-hatch) and only successful broods were used in the analyses. Six broods (33%) were in pastures with cattle and 12 broods were in pastures without cattle (67%). Grazing utilization level, grass height, and dominant sagebrush type were recorded at brood locations and were extrapolated to provide an estimate for each brood's home range. A two-sample t-test was used to test differences inn grass heights and brood home range size between years, grazed/ungrazed pastures, and dominant sagebrush types. Grazing utilization levels were 4% in brood home ranges across both years of the study. There was no year effect in grass heights. Grass heights did not differ between grazed and ungrazed pastures or across the mountain big sagebrush (*Artemisia tridentata ssp. vaseyana*) and three-tip sagebrush (*A. tripartita*) habitats the broods used. There was no year effect in brood home range size. Brood home range size did not differ by grazed (n=6) and ungrazed (n=12) pastures or across the two sagebrush types the broods used. The grazing

utilization levels were low enough that cattle did not have a significant effect on the grass heights in grazed pastures. The stocking rate in that pasture was 4 ha per AUM which is 1/3 of the recommended stocking rate. Current grazing practices in the Centennial Valley appear to have no effect on the home ranges of sage-grouse broods.

Keywords: Greater sage-grouse (*Centrocercus urophasianus*), cattle, grazing, utilization, home range, sagebrush (*Artemisia spp.*), brood.

Introduction

Greater sage-grouse (*Centrocercus urophasianus*, hereafter referred to as sage-grouse) is a sagebrush obligate species that has declined range-wide since the 1950s (Connelly and Braun 1997, Connelly et al. 2004, Gregg and Crawford 2009). The U.S. Fish and Wildlife Service declared that sage-grouse are not warranted for listing under the Endangered Species Act on September 22, 2015. This decision is up for review in five years (U.S. FWS 2015). If listing occurs, this would cause a major revision in the current multiple-use management that dominates roughly 70% of the sagebrush (*Artemisia spp.*) habitats (Box 1990, Poling 1991, Connelly et al. 2004). Sage-grouse rely on the structural attributes of sagebrush habitats for food and cover (Beck et al. 2011) and federal agencies manage 66% of the sagebrush habitats in the U.S. (Connelly et al. 2004). In those sagebrush habitats, livestock grazing is the most prominent land use (Connelly et al. 2004). Grazing leases on public lands provide a substantial amount of forage for livestock producers. High grazing intensity characterized by long duration and high stocking rates has been cited as a threat to sagebrush habitats (Beck and Mitchell 2000,

Hayes and Holl 2003, Crawford et al. 2004, Aldridge et al. 2008). Removal of nesting cover due to grazing has been shown to increase predation and alter nest site selection (Gregg et al. 1994). Indirect effects of cattle grazing such as the removal of nesting cover has been widely studied, but the direct effects of cattle presence on sage-grouse are not well understood (Beck and Mitchell 2000). Cattle have been believed to be able to cause the abandonment of nests (Coates et al. 2008), but how their presence and herbivory affect broods (e.g. hen with ≥1 chick) have largely been unstudied (Beck and Mitchell 2000). Brood survival is one of the most important parameters that influences population growth and long-term viability of sage-grouse (Taylor et al. 2010). Home ranges for sage-grouse broods ranged from 100-700 ha in size (Wallestad 1971, Connelly and Markham 1983, Gates 1983, Drut et al. 1994b). Several studies have observed large spatial movements of sage-grouse broods to riparian areas due to higher availability of forbs and insects (Gill 1965, Klebenow 1969, Savage 1969, Connelly and Markham 1983, Gates 1983, Connelly et al. 1988, Fischer et al. 1996, Connelly et al. 2000). Drought conditions may exacerbate the need for sage-grouse broods to be able to access riparian areas (Connelly et al. 2000). Cattle tend to congregate around riparian areas (Martin and Ward 1970, Squires 1978, Gillen et al. 1984, Pinchak et al. 1991) which could cause possible conflicts if sage-grouse broods and cattle are selecting for the same area. Lupis (2005) found with Gunnison sage-grouse (*Centrocercus minimus*) males and broodless hens avoided grazed pastures, whereas the only hen with a brood did not show avoidance for those grazed pastures. Utilization levels in that study ranged from 65-80%, which is much greater than the Sage-Grouse Initiative (SGI) recommendations of a

maximum of 50% utilization levels (Stinson 2014). Foster et al. (2015) found that 47% of brood locations were in pastures with livestock and avoidance of these cattle occupied pastures was not observed. If sage-grouse broods are avoiding sites that are occupied by cattle than we expect that brood home range size to be larger in pastures with cattle.

Methods

Study Area

Our study area is located in the Centennial Valley of southwest Montana. The Centennial Valley is a high elevation valley (>2000 m) that contains large expanses of sagebrush habitats that include several leks that belong to a sparsely studied population of sage-grouse. Also, the Centennial Valley belongs to the Montana Sage-Grouse Core Area 10. The Core Areas of Montana represent <10% of the land area, but supports >50% sage-grouse population in the state (NRCS 2010, Foster et al. 2015). Eight leks found across the entire length of the valley (~100 km) were the focus for this study. The Fish Creek Lek was the largest lek which had an average of 100 males in the previous five years (US FWS, *unpublished data*). The four main sagebrush species present in the valley are mountain big sagebrush (*Artemisia tridentata ssp. vaseyana*) and three-tip sagebrush (*A. tripartita*), basin big sagebrush (*A. tridentata ssp. tridentata*), and low sagebrush (*A. arbuscula*; US FWS 2009)**.** Our captured sage-grouse dispersed to ~40,000 ha and encompassed land controlled by several different federal, state, and private agencies (e.g. Fish & Wildlife Service, The Nature Conservancy, Bureau of Land Management,

Montana Department of Natural Resources and Conservation). Private landowners also represent some of the land ownership.

Field Methods

Hens were captured near leks using a combination of spotlighting/dip netting techniques during the spring breeding season (Giesen et al. 1982, Wakkinen et al. 1992). Immediately after capture, hens were aged, banded and collared. The hens were fitted with VHF transmitters (American Wildlife Enterprise, Monticello, FL) and then released. The locations were recorded several times a week throughout the brood-rearing season to determine habitat selection and home ranges. Broods were monitored until the chicks were 30 days old. The chicks became largely independent and were not completely reliant on their mother for thermoregulation at ~30 days old (Schroff, *personal observation*). Furthermore, chick mortality most often occurs within 28 days post-hatch (Gregg et al. 2007, Dahlgren et al. 2010). Consequently, we declared a brood successful if at least 1 chick survived to 30 days post-hatch and at that point they were no longer monitored.

In 2014, to estimate grazing utilization levels, permanent transects were laid out in advance of cattle being brought into a pasture (3900 ha) that was occupied by sage-grouse broods. These transects were laid out randomly and stratified across three estimated grazing levels of low, medium, and high. Each area of the pasture was separated into one of those three estimated grazing utilization levels. Low utilization sites were in areas that were far from water sources (e.g. >500 m from a water source) and/or on steep terrain (e.g. >30% slope; Holechek 1988). Medium utilization sites were in areas

that were a moderate distance from water (e.g. 250-500 m from a water source) and/or on gentle to moderate terrain (e.g. 11-30% slope; Holechek 1988). High utilization sites were in areas that were close to water (e.g. <250 m from a water source) and/or on gentle terrain (e.g. <10% slope; Holechek 1988). There were highly available water sources found throughout the pasture, so no sites in our pastures were farther than 1600 m from water (Holechek 1988). Therefore, we used different distances from water to predict cattle use based on our personal observations. Ten transects were laid out in random locations estimated to be in low grazing utilization areas, 10 transects were laid out in random locations estimated to be in medium grazing utilization areas, and 10 transects were laid out in random locations estimated to be in high grazing utilization areas for a total of 30 transects across the entire pasture. Transects were randomly laid out before cattle were brought in and located in areas with no visible signs of wild ungulates utilization [e.g. elk (*Cervus canadensis*), pronghorn (*Antilocapra americana*), mule deer (*Odocoileus hemionus*)]. Therefore, all transects had 0% utilization level when they were established. Each transect was then measured twice after that, once during the mid-point of when the cattle are in the pasture and again within a few days after the cattle have been taken off the pasture. Each transect was 30 m long and a line point intercept (LPI) was used to estimate the amount of grazing utilization that has occurred (Herrick et al. 2005). At each 0.5 m along the transect, a pin was dropped and the height of the grass species that was touching or nearest to the pin was recorded along with whether it has been grazed or not. If the plant was grazed then the height of the nearest ungrazed plant of the same species was measured as well. Those two heights were later used to estimate the

portion removed by grazing to estimate weight removed. A height-weight regression curve (Coulloudon et al. 1999) was constructed for each grass species that was grazed in our study area. Idaho fescue (*Festuca idahoensis*), smooth brome (*Bromus inermis*), Sandberg's bluegrass (*Poa secunda*), basin wildrye (*Elymus cinereus*) were clipped in order to create height-weight regression curves for our study area (see Appendix). These grass species were clipped and dried at two time periods in 2014. Individual plants were clipped in 5 cm increments and weighed with each of those portions removed. Therefore, we could estimate weight removed at a certain grazed height of a grass species. Additional height-weight regression curves of other less commonly grazed species were constructed from the U.S. Forest Service Utilization Gauge (U.S. Forest Service 1980). In 2015, we had only two broods in pastures with cattle, each in a separate pasture. Therefore, utilization levels were measured at brood locations and at paired random locations because those brood home ranges represented a small portion of the pasture. Similar vegetation surveys were conducted at brood locations and paired random locations for broods located in pastures without cattle, but with only grass heights and habitat type recorded rather than utilization levels. Utilization levels were assumed to be 0%, since livestock were not present in those pastures and there were no visible signs of utilization by wild ungulates.

Statistical Analyses

Brood locations and vegetation surveys were uploaded into ArcMap 10.2. Home ranges were calculated using minimum convex polygons (MCPs; Fig. 6) in order to estimate the area used by sage-grouse broods (Mohr 1947). MCPs were used instead of

adaptive or fixed kernels because those analyses require larger sample sizes (n≥30; Kernohan et al. 2001). Our sample sizes ranged from 8 to 22 locations per brood. Using the kriging function in ArcMap 10.2, the utilization levels, grass heights, and the dominant sagebrush type were extrapolated to estimate the average values for those habitat variables for each individual brood's home range.

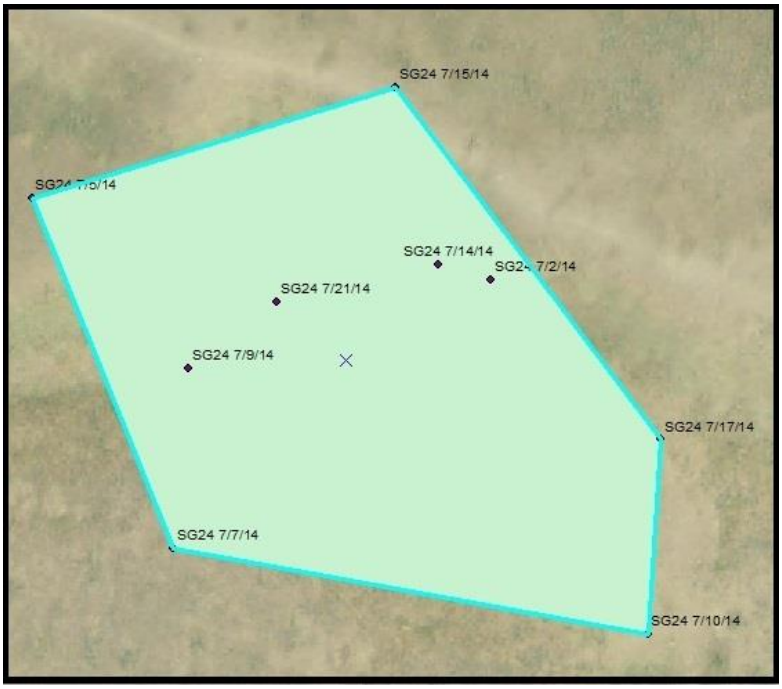

Figure 6. A minimum convex polygon (MCP) used to estimate a greater sage-grouse brood's home range in the Centennial Valley, MT, 2014-2015.

A two sample t-test was used to determine if there was year effect for any of the habitat variables. If no year effect was found then both years were combined into the succeeding analyses. Two sample t-tests were used to test if there was a difference between grass heights in grazed and ungrazed pastures as well as across sagebrush type.

Two sample t-tests were used to test if there was a difference between home range size in broods in grazed and ungrazed pastures, as well as across sagebrush type.

Results

A total of 111 sage-grouse hens were captured across two breeding seasons (2014-2015). These collared sage-grouse initiated 90 nests which produced 18 successful broods (Table 4). Fourteen percent of the broods in pastures with cattle failed. However, only successful broods were used in analyses.

Table 4. Total number of successful greater sage-grouse broods in pastures with and without cattle in the Centennial Valley, MT, 2014-2015.

Pastures	**2014**	**2015**	**Total**
Broods with Cattle	4	2	6
Broods without Cattle	7	5	12
Total	**11**	**7**	**18**

Grazing utilization levels were on average 4% in brood home ranges across both years of the study (Table 5). The maximum utilization level recorded in a brood's home range was 14%. In 2014, the average utilization for the entire pasture was 10% with a maximum utilization level recorded at 52%. Therefore, utilizations levels were low in brood home ranges and across most of the pasture.

Table 5. Grazing utilization levels in greater sage-grouse brood home ranges in pastures with cattle and across the entire pasture in the Centennial Valley, MT, 2014-2015.

Utilization Levels (%)	**2014**	**2015**	**Average**
Average in Brood Home Ranges	4	3	4
Maximum in Brood Home Ranges	14	13	14
Average in Overall Pasture	10	N/A†	N/A‡
Maximum in Overall Pasture	52	N/A†	N/A‡

† Utilization levels were recorded at brood locations and not for the entire pasture in 2015

‡ Utilization levels for the entire pasture were not available for 2015, so averages for both years could not be calculated

There was no significant difference in grass heights in brood home ranges across both years of the study (Table 6). Precipitation levels were similar across both years from April through June (10.9 cm=2014, 11.7 cm=2015) of the study which was slightly above the 25 year average (10.8 cm; Western Regional Climate Center 2016). Grass heights were not significantly different across pastures grazed and ungrazed. Also, there was no significant difference in grass heights between sites dominated by mountain big sagebrush and those dominated by three-tip sagebrush plants.

Table 6. Differences in average grass heights between years, pastures with/without cattle, and across sagebrush types of greater sage-grouse brood home ranges in the Centennial Valley, MT, 2014-2015.

Two Sample T-Test	Means (cm)		P-Value
	2014	**2015**	
Year Effect (n=199)	27	33	0.39
	Grazed	**Ungrazed**	
Grazed (n= 92) vs. Ungrazed (n=87)	37	26	0.18
	Mountain Big Sagebrush	**Three-tip Sagebrush**	
Mountain Big Sagebrush (n=97) vs. Three-tip Sagebrush (n=56)	30	31	0.89

Brood home range sizes varied from 4-313 ha with an average of 111 ha (Table 7). There was no significant difference in brood home range size across both years of the study. Brood home range size was not significantly different across pastures which were grazed and ungrazed. Also, there was no significant difference in brood home range size between mountain big sagebrush and three-tip sagebrush habitats.

Table 7. Differences in greater sage-grouse brood home range size between years, pastures with/without cattle, and across sagebrush types in the Centennial Valley, MT, 2014-2015.

Two Sample T-Test	Means (ha)		P-Value
	2014	**2015**	
Year Effect (n=18)	102	142	0.66
	Grazed	**Ungrazed**	
Grazed (n=6) vs. Ungrazed (n=12)	149	91	0.35
	Mountain Big Sagebrush	**Three-tip Sagebrush**	
Mountain Big Sagebrush (n=9) vs. Three-tip Sagebrush (n=7)	81	92	0.78

Discussion

There was no significant difference ($p>0.05$) between grass heights by year, by grazed/ungrazed pastures, or by sagebrush type in brood home ranges. Also, there was no significant difference of brood home range size by year, by grazed/ungrazed pastures, and by sagebrush type. The grazing utilization levels were low enough that cattle did not have a significant effect on the grass heights in grazed pastures or in the brood home

range size. Granted, the sample size for broods in pastures with cattle were low (n=6), but were larger than any other similar study (Lupis 2005). Also, we observed two broods that traveled greater than 1 km into a pasture with cattle where they remained for more than 2 weeks. In 2014, the average utilization for the entire pasture was 10% with a maximum utilization level recorded at 52%. The recommended stocking rate for our study area is 1.33 ha per animal unit month (AUM) and the stocking rate in our pasture was 4 ha per AUM, which is 1/3 of the recommended stocking rate (Lacey and Taylor 2005). Precipitation levels were slightly above average for both years, but peak runoff was three weeks earlier than normal in 2015 (US Fish & Wildlife Service, *unpublished data*). In a similar study on Gunnison sage-grouse (*Centrocercus minimus*) males and broodless hens avoided grazed pastures, whereas the only hen with a brood did not show avoidance for grazed pastures (Lupis 2005). Furthermore, the utilization levels in that study ranged from 65-80%, which is much greater than the Sage-Grouse Initiative (SGI) recommendations of 50% utilization level or "take half, leave half" (Stinson 2014).

Home range size for sage-grouse broods have been calculated to be from 100-700 ha in size (Wallestad 1971, Connelly and Markham 1983, Gates 1983, Drut et al. 1994b). Our home range sizes varied from 4-313 ha with an average of 111 ha. Unlike other studies, we did not observe any large spatial movements of our broods to riparian areas (Gill 1965, Klebenow 1969, Savage 1969, Connelly and Markham 1983, Gates 1983, Connelly et al. 1988, Fischer et al. 1996, Connelly et al. 2000). Other habitat variables are most likely to be the cause of the differences in our home range sizes. Selection of forbs (Drut et al. 1994b), insects (Blomberg et al. 2013), shrub canopy cover (Connelly et

al. 2000), or avoidance of predators (Dinkins et al. 2012) may all be influencing brood habitat use in our study area. Drut et al. (1994b) found that differences in home range size were best explained by the availability of forbs. The higher the forb abundance and the subsequent higher contribution of forbs in their diet were characterized by smaller brood home ranges in Oregon (Drut et al. 1994b). Mountain big sagebrush and three-tip sagebrush habitats appear to have higher abundances of forbs than basin big sagebrush habitats in the Centennial Valley, Montana. Foster et al. (2015) found that 70% of broods used pastures with livestock and 47% of all brood locations were in pastures with livestock. This suggests that broods are selecting areas based on other factors instead of livestock presence (Foster et al. 2015).

Current grazing practices in the Centennial Valley appear to have very little effect on sage-grouse. Most producers do not graze their cattle in the valley until later in the spring and summer due to the high elevation (e.g. >2000 m) of the valley and corresponding late snow melt. An abundance of the poisonous plant larkspur (*Delphinium spp.*) causes many producers to turn out later in the season. Therefore, cattle and sage-grouse generally only overlap during the brood-rearing time period during the summer and fall. Although, during this time period the cattle are generally concentrated in the near water sources and sage-grouse broods were using areas higher in elevation out of the valley bottoms. In conclusion, we saw very little spatial overlap between cattle and sage-grouse broods.

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CHAPTER FIVE

MANAGEMENT IMPLICATIONS FOR THESIS

Connelly et al. (2000) recommended guidelines for managing sagebrush habitats for breeding sage-grouse include sagebrush canopy cover of 15-25%, grass cover ≥15%, forb cover ≥10% and with the height of the herbaceous material averaging ≥18 cm. These guidelines were mainly developed in less productive, drier Wyoming big sagebrush (*Artemisia tridentata ssp. wyomingensis*) habitats. Currently, all sagebrush types are enrolled into the Sage-Grouse Initiative (SGI) at the same rate regardless of species or subspecies. Results from this study have shown that not all sagebrush habitats are equally productive for breeding sage-grouse. I suggest that certain sagebrush habitats should be prioritized over others when enrolling those acres into the SGI program for the Centennial Valley, Montana.

Mountain Big Sagebrush

Nest sites under mountain big sagebrush plants exceeded the recommended guidelines of the shrub canopy cover (44%) and did not meet the minimum forb cover (9%). Mountain big sagebrush nests only meet the rest of the herbaceous cover guidelines by new growth of grasses and not by residual cover. Mountain big sagebrush shrubs were used the most often for nest sites (45%) and those shrubs provided >50% of lateral cover. In conclusion, mountain big sagebrush habitats had the most nests, provided greater lateral cover to the nests and were used for brood-rearing. Therefore, enrollment of

mountain big sagebrush habitats into SGI should be given the highest priority above all other sagebrush types in the Centennial Valley, Montana.

Three-Tip Sagebrush

Nest sites under three-tip sagebrush plants did not meet the recommended guidelines of the shrub canopy cover (40%) nor the minimum forb cover (2%). Three-tip sagebrush nests only met the rest of the herbaceous cover guidelines by new growth of grasses and not by residual cover. Three-tip sagebrush shrubs were the second most common shrub used for nest sites (21%) and those shrubs provided >60% of lateral cover. Three-tip sagebrush has been determined to provide inadequate nesting cover for sage-grouse in other study areas (Patterson 1952, Connelly et al. 2000), but in our study area and at other sites (Klebenow 1969, Braun et al. 2005) it is an important sagebrush type for nesting and brood-rearing sage-grouse. In conclusion, three-tip sagebrush habitats had the second most nests, provided greater lateral cover to the nests and were used for brood-rearing. Therefore, three-tip sagebrush habitats should be given the second highest priority and enrolled into SGI at a higher rate than the other sagebrush types except mountain big sagebrush.

Basin Big Sagebrush

Nest sites under basin big sagebrush plants did not meet the recommended guidelines of the shrub canopy cover (29%), minimum forb cover (9%) and average grass height (12 cm). Basin big sagebrush nests only met the grass cover guideline by new growth of grasses and not by residual cover. Basin big sagebrush shrubs were the third

most common used shrub for nest sites (20%) and those shrubs provided ≤25% of lateral cover. Basin big sagebrush had less than half the lateral cover that other species/subspecies of sagebrush provided. Due to its taller growth form, basin big sagebrush did not provide the same amount of cover that other sagebrush species provided. In conclusion, basin big sagebrush habitats had the third most nests, provided less lateral cover to the nests and were not commonly used for brood-rearing. Therefore, basin big sagebrush habitats should be given the third highest priority and enrolled into SGI at a lower rate than mountain big sagebrush and three-tip sagebrush habitats.

Low Sagebrush

Low sagebrush did not meet any of the recommended guidelines and was not used as nest sites. Residual cover values for all nest sites were much lower than the recommended guidelines (e.g. >10% residual cover with heights >18 cm; Connelly et al. 2000). Low sagebrush does provide lekking habitat in the Centennial Valley, but was not used by nesting or brood-rearing sage-grouse. In conclusion, low sagebrush habitats had no observed nests and were only used by males and broodless hens. Therefore, low sagebrush habitats should be given the lowest priority and enrolled at a lower rate than all the other sagebrush habitats.

Grazing

Grazing practices during our study in the Centennial Valley appear to have minimal to nonexistent effects on sage-grouse (2014-2015). Most of the nest sites (98%) selected by our collared hens were located in areas that do not experience grazing until

after the nesting season (e.g. first week of July). Even in pastures that have been rested >6 years, residual lateral cover was not present in any abundance. Fifty-two percent of the nests had no residual lateral cover. New growth of grasses and forbs were the main herbaceous lateral cover present at nests, but may not have been present when the hen selected the nest site. Nests were measured after the hen left the area which could have been up to 45 days later than when the hen started laying eggs. Therefore, new growth may not have been present when the hen was selecting a nest site.

Generally, cattle and sage-grouse overlap during the brood-rearing time period in the summer and fall. Cattle stocking rates during our study were 1/3 of recommended stocking rate. Average utilization level for the entire pasture was 10% with a maximum utilization level recorded at 52% in 2014; which is well below the SGI recommendations of not exceeding 50% utilization levels (Stinson 2014). Furthermore, there was no measurable effect in the home range size of broods in pastures with cattle compared to broods in pastures without cattle. Cattle presence and herbivory did not alter the areas used by broods. This is further strengthen by the observation of 2 broods traveling greater than 1 km into a pasture with cattle where they remained for more than 2 weeks. Additional research is needed of sage-grouse broods that occupy pastures that are subjected to higher utilization levels by livestock to estimate if there is a threshold of the amount of herbage removed that sage-grouse will select against.

Conclusion

Sagebrush represented the most important class of shrubs used as nest sites (89%). Furthermore, 66% of all the nests were located under mountain big sagebrush and

three-tip sagebrush. These species/subspecies provided the most lateral cover to the nest. Also, mountain big sagebrush and three-tip sagebrush habitats were the main sagebrush types used for brood-rearing. Therefore, managers should focus on conserving large tracts of mountain big sagebrush and three-tip sagebrush habitats because they provide more concealment for nests and were selected for more often as nest sites and brood-rearing locations than other sagebrush species/subspecies in the Centennial Valley, Montana.

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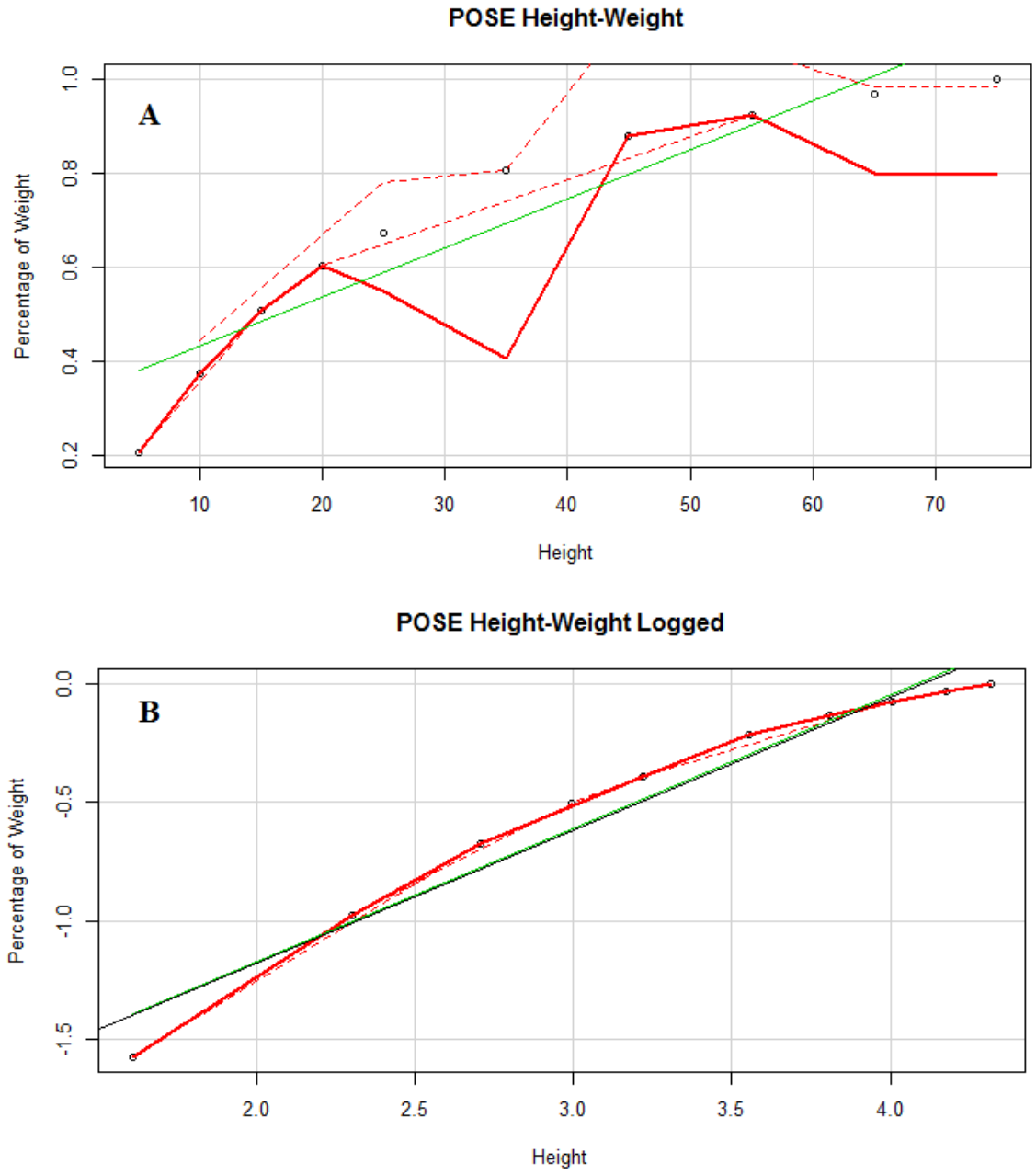
APPENDICES

APPENDIX A

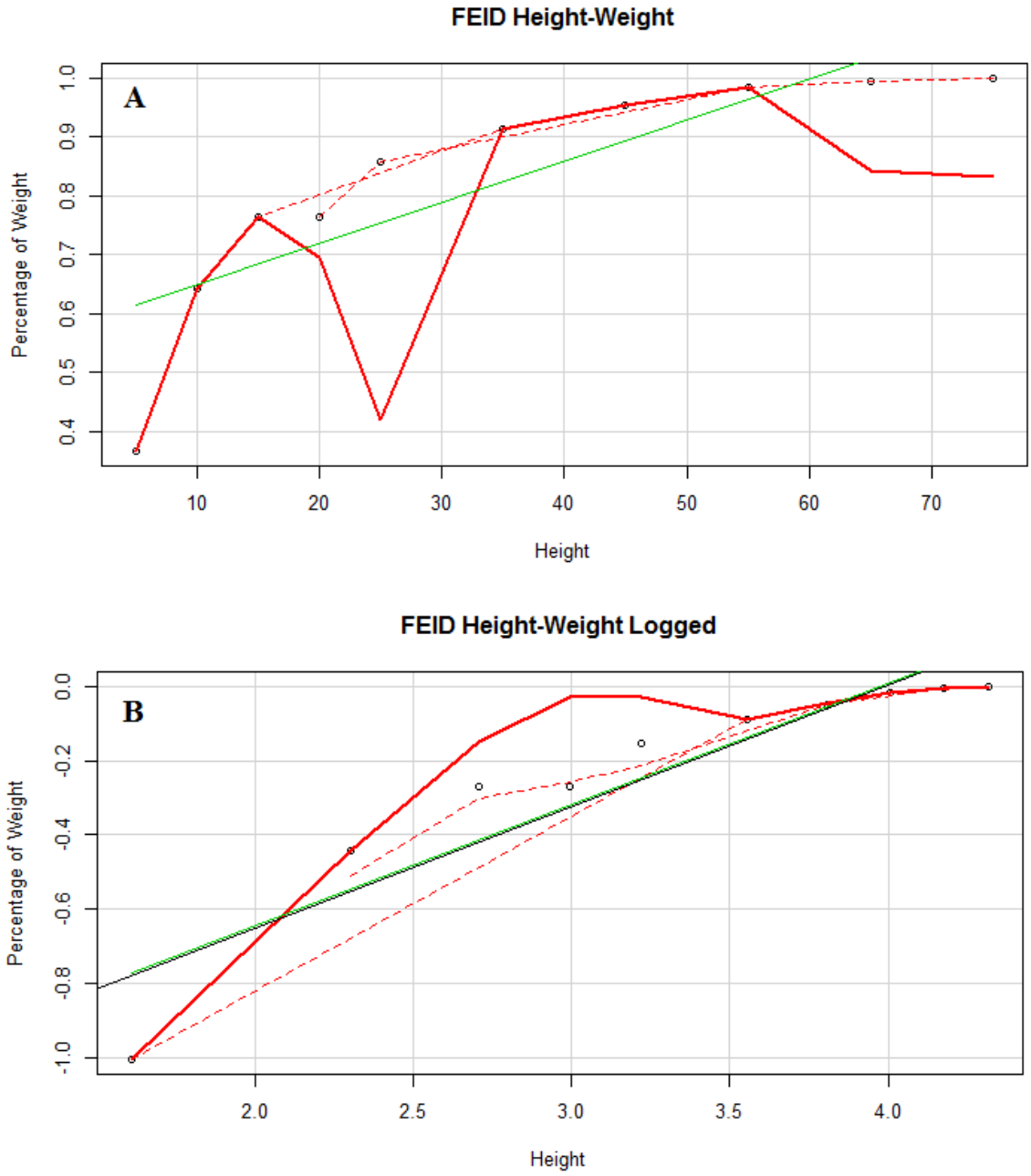
HEIGHT-WEIGHT REGRESSION CURVES FOR SANDBERG'S BLUEGRASS



APPENDIX A. Height-weight regression curves for **A,** raw values and **B,** logged values for Sandberg's bluegrass (*Poa secunda*) built for the Centennial Valley, Montana, 2014-2015. Solid red lines represent means, solid green lines represent abline, and dotted lines represent 95% confidence intervals.

APPENDIX B

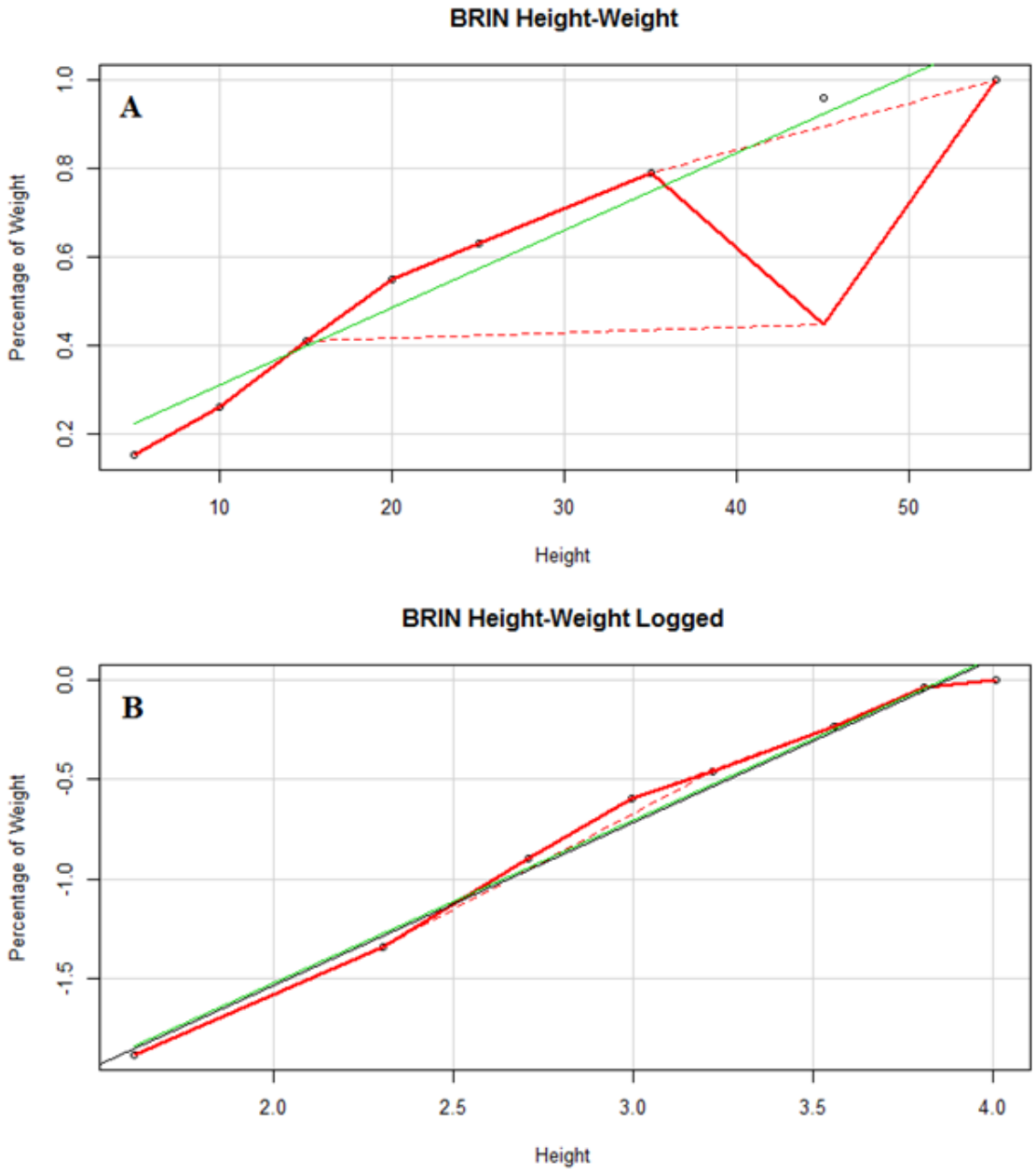
HEIGHT-WEIGHT REGRESSION CURVES FOR IDAHO FESCUE



APPENDIX B. Height-weight regression curves for **A,** raw values and **B,** logged values for Idaho fescue (*Festuca idahoensis*) built for the Centennial Valley, Montana, 2014-2015. Solid red lines represent means, solid green lines represent abline, and dotted lines represent 95% confidence intervals.

APPENDIX C

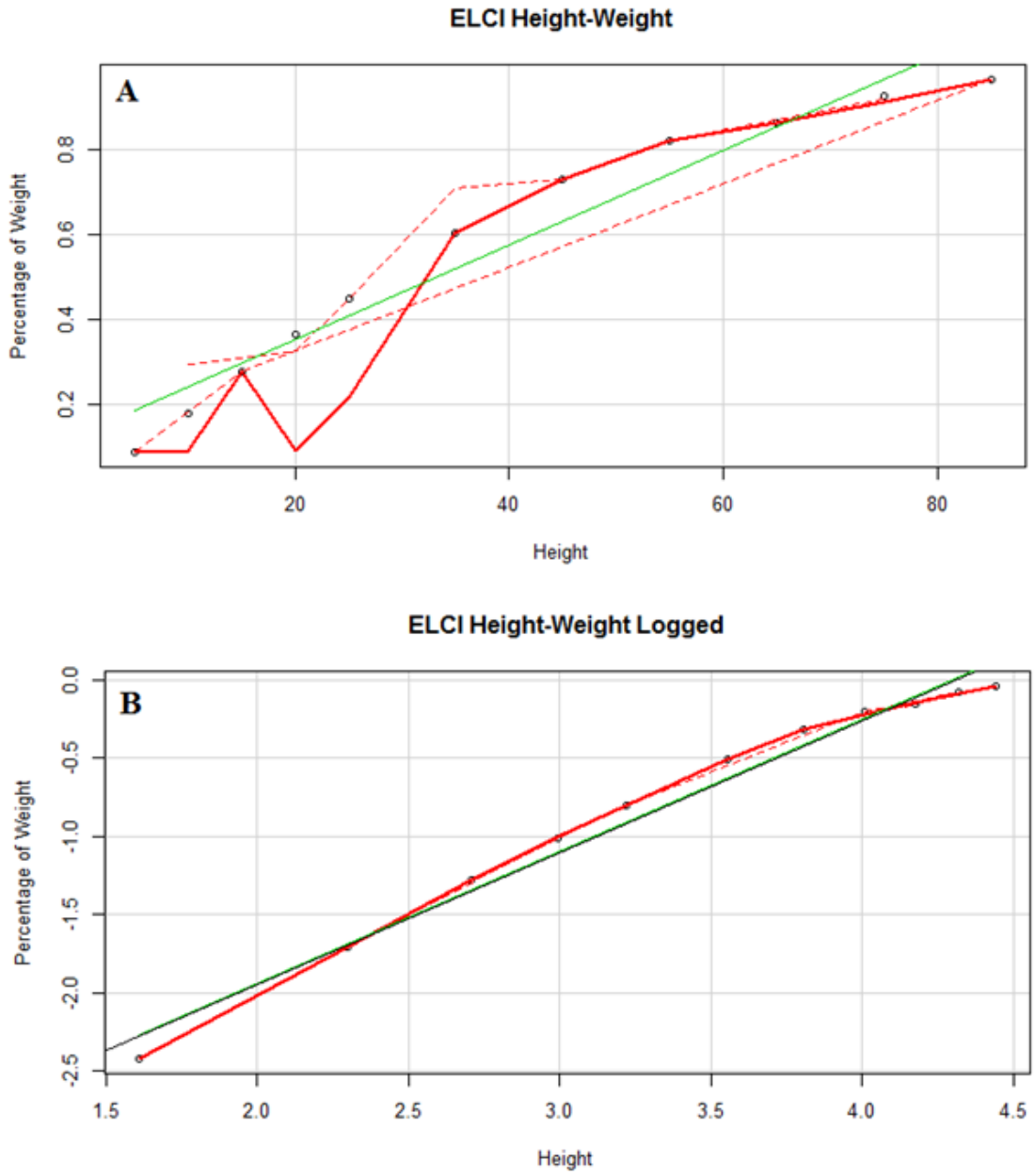
HEIGHT-WEIGHT REGRESSION CURVES FOR SMOOTH BROME



APPENDIX C. Height-weight regression curves for **A,** raw values and **B,** logged values for smooth brome (*Bromus inermis*) built for the Centennial Valley, Montana, 2014-2015. Solid red lines represent means, solid green lines represent abline, and dotted lines represent 95% confidence intervals.

APPENDIX D

HEIGHT-WEIGHT REGRESSION CURVES FOR BASIN WILDRYE



APPENDIX D. Height-weight regression curves for **A,** raw values and **B,** logged values for basin wildrye (*Elymus cinereus*) built for the Centennial Valley, Montana, 2014-2015. Solid red lines represent means, solid green lines represent abline, and dotted lines represent 95% confidence intervals.